United States Department of Agriculture
Agricultural Research Service

National Program 305 • Crop Production

FY 2020 Annual Report

The Crop Production National Program (NP 305) supports research to develop knowledge, strategies, systems, and technologies that contribute to greater cropping efficiency, productivity, quality, marketability, and protection of annual, perennial, greenhouse, and nursery crops, while increasing environmental quality and worker safety.

The Nation's rural economic vitality depends on the ability of growers to profitably produce and market agricultural products including food, fiber, flowers, industrial products, feed, and fuels, while enhancing the natural resource base of crop production. Future financial success depends on increasing productivity, accessing new markets for specialized products, developing technologies to provide new opportunities for U.S. farmers, and utilizing tools and information to mitigate risks and enable rapid adjustments to changing market conditions. The farm sector has great and varied needs driven by a wide variety of resource, climatic, economic, and social factors that require an equally diverse array of solutions.

Contemporary cropping enterprises are complex and depend on highly integrated management components that address crop production and protection, resource management, mechanization, and automation. U.S. annual, perennial, and controlled environment crop production (e.g., greenhouse and other protected systems) are based on the successful integration of these components. The development of successful new production systems requires a focus on new and traditional crops; the availability and implementation of improved models and decision aids; cropping systems that are profitable and productive; production methods fostering conservation of natural resources; efficient and effective integrated control strategies for multiple pests; improved methods, principles, and systems for irrigation; improved mechanization; and reduced inputs – all while sustaining or increasing yield and quality.

Production systems must better address the needs of small, intermediate, and large farming enterprises including those using field-, greenhouse-, orchard-, and vineyard-based production platforms with conventional, organic, or controlled environment strategies. Additionally, adaptation and development of technologies are required to ensure a sustainable and profitable environment for production agriculture. New technologies must address the need for lower cost, higher efficiency inputs that foster conservation of energy and natural resources, while maintaining profitability and promoting environmental sustainability.

In addition, declining bee populations and honey production require special attention. Over the past several years, a myriad of pests and potentially adverse cultural and pest management practices have been threatening many of the bee species required for pollination of multitudinous crops. Colony Collapse Disorder had increased honey bee (*Apis*) over-wintering mortality to over 30 percent; and while CCD incidence has declined, bee mortality remains unsustainably high. Also, as new crops or niches are introduced, there is an increasing need for non-honey bee pollinators for specific crops or protected environments.

National Program 305 coordinates and collaborates extensively with other ARS National Programs, universities, and industries in adapting and incorporating technologies, approaches, and strategies that enable the advancement of the Nation's agricultural industry and enhanced international competitiveness.

This National Program is divided into two main research components:

- **Component 1: Integrated Sustainable Crop Production Systems**
- **Component 2: Bees and Pollination**

Below are National Program 305 accomplishments from fiscal year 2020, grouped by research component. This report is not intended to be a progress report describing all ongoing research, but rather an overview that highlights accomplishments, some of which are based on multiple years of research (not all research projects will reach an "accomplishment" endpoint each year).

ARS welcomes your input regarding our ongoing research programs. If you have any questions, please do not hesitate to contact the National Program 305 team: Kevin Hackett (kevin.hackett@usda.gov), Joe Munyaneza (joseph.munyaneza@usda.gov), Tim Rinehart (tim.rinehart@usda.gov), Jack Okamuro (jack.okamuro@usda.gov), and Roy Scott (roy.scott@usda.gov)

Component 1 – Integrated Sustainable Crop Production Systems

Universal intelligent spray control system as a retrofit for conventional sprayers commercialized. An intelligent spray technology developed by ARS researchers in Wooster, OH, effectively controls pest insects and diseases with significant reductions in pesticide waste to the environment; however, to ensure that growers use this technology economically, it must be adaptable to conventional sprayers. To address this challenge, the researchers developed a universal intelligent spray system as a retrofit unit for conventional orchard sprayers. The retrofit unit was tested in 15 commercial nurseries, fruit and nut orchards, and vineyards in California, Ohio, Oregon, South Carolina, Tennessee, Texas, and Australia. Field tests demonstrate this new technology can provide pest and disease control that is as effective as conventional spray systems while reducing spray drift by up to 87 percent and ground loss by 90 percent. In addition, pesticide use was reduced by up to 85 percent, resulting in an annual chemical cost saving of $812 per acre, depending on crop type. This cost reduction does not include reductions in labor and fuel costs. The technology was transferred to a commercial partner and a commercial product, "Intelligent Spray Control System" by Smart Guided Systems, LLC, was released to the market. Citrus, apple, grape, nursery, and pecan growers in the United States and other countries have started to upgrade their sprayers with the commercial product. The use of a new laser-guided intelligent spraying system is beneficial to the environment and saves growers money. The ability to retrofit conventional sprayers offers a sustainable and environmentally responsible approach to protecting crops.

Pennycress as a cash cover crop promotes sweet corn sustainability. Commercial sweet corn production often results in substantial losses of nitrogen applied via fertilizer that end up in ground and surface waters as a pollutant. Growing a cover crop after sweet corn harvest to use excess leftover nitrogen could prevent this issue, but producers are reluctant to adopt this practice for economic reasons. ARS researchers in Morris, MN, in collaboration with University of Minnesota scientists, demonstrated that pennycress, which can double as an oilseed cover and cash crop, reduces the potential loss of leftover nitrogen from sweet corn production by about 42 percent. Moreover, the excess nitrogen that pennycress scavenges is enough to produce adequate pennycress seed yields without adding any additional fertilizer. Results of these studies are relevant to farmers, extension specialists, and crop consultants searching for cover crop options that are both economically and environmentally sustainable.

Novel methodology to prioritize the practice of healthy soils. Good soil-health management practices include cover cropping, compost, crop rotations, and reduced tillage. ARS researchers in Davis, CA, developed a novel way to identify where such practices may have had their greatest impact in the Central and Coastal valleys of California. They did this by refining the USDA Natural Resources Conservation Service's SSURGO database into regions of soil health identity that reflected crop performance and soil health management practices. Covering 5.6 million hectares, the California valleys support wine grapes, almonds, citrus, vegetables, and other high-value specialty crops. Outcomes of this research will result in a map of soil-health regions based on a complex range of soil properties. Such a map could help growers decide which practices to adopt to improve soil health, given limited labor and revenue.

Satellite imagery for discriminating co-existing crop diseases and pests. Successful monitoring and management of crop health and pests to guide efficient crop production and protection inputs requires high-quality and timely remotely sensed data. ARS researchers in College Station, TX, developed new methods that use Landsat-8 satellite imagery to detect the presence of powdery mildew and aphids and damage from those pests in winter wheat, which in turn, will be used to guide site-specific pest management. The researchers integrated plant growth and other location-specific environmental information into early detection and monitoring algorithms, which led to the development of prescription maps to guide management efforts. The new methods and results from this work are immediately applicable across a wide variety of crop pest types in precision agriculture. Adoption of the new methodology will result in reduced pesticide input while maintaining or improving overall pest management efficacy.

Critical temperatures for preventing fruit damage in blueberries. The blueberry industry loses millions of dollars each year due to heat damage to fruit. To contend with this problem, many growers are installing micro-sprinkler systems to cool the berries but have many questions about their use, including the temperature at which to run their systems. ARS scientists in Corvallis, OR, with collaborators at Oregon State University, determined that to avoid damage, fields should be cooled when air temperatures are >90°F when the berries are green and >95°F when the berries are pink or blue. Growers are using this information to decide when to initiate cooling and avoid disastrous fruit losses from heat damage.

Adding silicon to soilless substrates improves horticultural crop production. Silicon is a beneficial soil element that can help mitigate many abiotic and biotic stresses such as management of cold stress, but limited research exists on suitable silicon sources, method of application, and application rates. ARS researchers in Toledo, OH, successfully quantified plant silicon uptake by basil, pepper, spinach, and tomato using commercially available silicon-containing soilless substrate amendments. Findings of this research have led to grower trials at research and commercial greenhouses and increased adoption of incorporating silicon as a soil amendment.

Improved aerial pesticide spray swath analysis method developed. Aerial application systems require that spray nozzles be properly placed across the boom to maximize the uniformity of deposition across the swath and to maintain optimum spacing between flight lines. Additionally, ensuring that spray deposition rate and droplet size across the area of application meet label requirements is critical to ensuring efficacy and minimizing off-target damage. ARS researchers in College Station, TX, developed better methods and new analytical techniques to quantify spray rate and droplet size to correspond with changes in effective swath width and wind direction. Before this research, scientists had only a limited understanding of the effects of crosswinds on deposition patterns from aerial spray systems. These new methods are being used by professional, manned aerial applicators and by researchers studying unmanned aerial applications in an effort to improve spray efficiency and efficacy while mitigating nontarget impacts.

Biochar promotes blueberry plant growth and root colonization by beneficial fungi. Biochar is a carbonaceous byproduct of bioenergy production and is attracting particular interest for its use as a soil amendment for agriculture. ARS scientists in Corvallis, OR, with collaborators at Oregon State University, evaluated the use of biochar produced by a wood debris-fired power plant as a soil amendment for blueberry, and discovered that its use resulted in a 70 percent increase in plant growth. The percentage of roots colonized by mycorrhizal fungi was also greatly increased. These fungi are well known to be beneficial for many crops, including blueberry. These findings provide valuable new information that will help growers improve soil health and increase production of blueberries.

Automatic classification of cotton root rot disease based on remote sensing. Cotton root rot is a persistent and destructive fungal disease of cotton in the southwestern and south-central United States. Although cotton root rot can now be mitigated using the Topguard Terra (FMC, Philadelphia, PA) fungicide, the high treatment cost requires that it be applied only to infested areas. ARS researchers in College Station, TX, working with Texas A&M University collaborators, developed two new automated methods to classify cotton root rot that take advantage of highresolution imagery acquired using unmanned aerial vehicles (UAVs). The new automatic methods gave a higher degree of accuracy than existing conventional classification methods. The methodology and results from this research provide another useful tool to growers for site-specific management of cotton root rot as more and more growers use UAVs to monitor crops and detect disease.

Best fertilizer practices for organic production of blueberries. Consumer demand for organic blueberries is increasing in the United States, but information on organic practices for the crop are needed. To address this issue, an ARS scientist in Corvallis, OR, with collaborators at Oregon State University, conducted a 10-year trial evaluating a variety of organic practices for blueberry, including the use of compost and organic fertilizers. Compost was found to be a good source of nutrients, but added considerable weed management costs during production and, over time, led to potentially toxic levels of potassium in the plants. Fish soluble fertilizer was also high in potassium and resulted in lower yields in certain cultivars. Feather meal was a good substitute for fish soluble fertilizer and, when combined with raised beds and weed mat mulch, had a positive effect on yield and fruit quality. Growers are currently using this information to manage their plantings and improve organic production of blueberries.

Long-lasting insecticide netting for protecting horticultural trees from ambrosia beetles. Ambrosia beetles are destructive wood-boring insects of ornamental and horticultural trees. Alternatives to trunk applications of conventional insecticides are needed to reduce nontarget drift and negative impacts on pollinators. Netting impregnated with insecticides has shown promise for protecting fresh cut logs from wood-boring bark and ambrosia beetles, but the tactic has not previously been evaluated using horticultural trees. ARS researchers in Wooster, OH, led a team of multistate scientists to evaluate using a long-lasting insecticide netting to protect stems against ambrosia beetles. In trials in four states, treated netting reduced attacks more than untreated netting did, and more than trees that were unprotected. In addition, fewer ambrosia beetle specimens were recovered from trees that were protected with treated netting compared with untreated netting. These results indicate that long-lasting insecticide netting could be used to protect horticultural trees from ambrosia beetles and minimize nontarget impacts of conventional insecticide sprays.

A new method for tracking crop water use. Low cost and reliable ground-based sensor systems are needed to complement remote sensing efforts to quantify crop water use. ARS researchers in Davis, CA, in collaboration with researchers at University of California, Davis, used infrared radiometers (standard equipment that measures canopy temperatures) at semi-high frequency to measure water use by a single plant. Such durable and affordable sensors can simultaneously measure water use and drought stress, and further serve to give added truth to our remote-sensing data. Canopy temperatures exhibited features that represent the energy exchanged between the air and the canopy. A wavelet analysis was used to quantify those features and found a strong correlation between water use measured with this new method and those measured by nearby flux towers.

Improved substrate models lead to higher precision irrigation. Specialty crops are increasingly being produced in containers in which the growing media consist primarily of pine bark or sphagnum peat. Little is known about the amount of water retained in the media for plant use and the daily wetting and drying that dictates irrigation. ARS researchers in Wooster, OH, successfully developed and validated a model to understand the amount of water applied, retained, and lost from growing media. The model provides a lower cost method for analyzing the properties of newly developed growing media, and provides guidance on how to deliver more precise irrigation and avoid excess runoff of water that may contain agrichemicals. Precision irrigation developed from these models will benefit specialty crop growers and consumers through lower production costs and ecosystem preservation.

Evidence of trunk-pathogen spores in young vineyards highlights the need for preventive practices. The timing for implementing practices to prevent grapevine trunk diseases (December to March) is based in part on high spore counts of the causal fungi that are reported in published studies from mature, symptomatic vineyards. The relevance of such data to young, asymptomatic vineyards, however, is not clear. ARS researchers in Davis, CA, compared spores collected over 4 years in two wine-grape crush districts (Napa and San Joaquin) in six young versus six mature vineyards. From 769 spore-trap samples, a combination of culture- and DNA-based methods qualitatively detected 19 species of fungal pathogens that cause dieback-type trunk diseases. The presence of virulent pathogens *Neofusicoccum parvum* and *Eutypa lata* at similar levels in both young and mature sites make it clear that growers should adopt practices to prevent grapevine trunk disease in young vineyards.

Differentiation of redroot pigweed from cotton plants based on canopy light reflectance. Redroot pigweed is a nuisance weed that affects cotton growth and yield worldwide. Being able to distinguish this weed from cotton would help producers and crop consultants better implement ways to suppress and control it. ARS researchers in Stoneville, MS, determined that redroot pigweed could be differentiated from cotton plants based on the light reflectance properties of their canopies. Light reflectance that was sensitive to leaf pigments, leaf orientation in the plant canopy, and leaf water content were found to be optimal for separating redroot pigweed and cotton. Commercial imaging systems used on ground-based or airborne platforms can be easily tuned into the spectral bands used by the researchers, thus providing managers with a precision agriculture tool to use against redroot pigweed in cotton production systems.

Improved diagnostic sampling protocol for detection of citrus Huanglongbing (HLB) pathogen, *Candidatus* Liberibacter asiaticus (CLas), in citrus trees. Detection of CLas in citrus trees is challenging in the absence of HLB symptoms. Frequently, samples collected from CLas-infected trees test negative for infection when in fact the tree is infected (i.e., a false negative). Research was conducted by ARS scientists in Fort Pierce, FL, to determine whether a hierarchical sampling strategy at the tree level could reduce the probability of false negative diagnoses of CLas. The sampling scheme is based on where CLas is most likely to be found in a tree. Results demonstrated that CLas infections can be detected within 24 hours after infection occurs. Based on these results, the official APHIS sampling protocol is now being revised.

Fertilizer sulfur can increase cane and sugar yields in Louisiana sugarcane. Recommendations that farmers in Louisiana use sulfur fertilizer were made before State and Federal regulations resulted in significantly reduced atmospheric deposition of sulfur. Sulfur levels in many Louisiana sugarcane fields have decreased, suggesting that current recommendations may be too low. ARS scientists in Houma, LA, initiated studies using clay and silt loam soils in fields to determine the optimum sulfur requirements for newly released Louisiana varieties of sugarcane. Results from the trials indicate that all varieties benefited from an application of sulfur. Data from multiple trials have demonstrated significant cane and sugar yield responses to sulfur rates greater than current recommendations, which suggests that current sulfur recommendations are too low and should be revised.

Component 2 – Bees and Pollination

Microalga as a promising nutritional supplement for honey bees. Feeding honey bees an artificial pollen substitute diet to support colony health during periods of reduced forage is a common management practice by beekeepers, but most substitute diets need improvement. Artificial diets may be deficient in essential macronutrients (proteins, lipids, prebiotic fibers), micronutrients (vitamins, minerals), and antioxidants. In an effort to improve artificial diets, ARS researchers in Baton Rouge, LA, evaluated the nutritional aspects of the microalga *Arthrospira platensis* (commonly called spirulina), finding that spirulina is rich in the essential amino acids and functional lipids commonly found in pollen. Nutritional physiology and microbiome evaluations of bees fed spirulina closely matched those of bees fed a natural pollen diet. The study results thus show that the alga has significant potential to serve as a pollen substitute or prebiotic diet additive to improve honey bee health. Results of the study were highlighted in the August 2020 edition of *American Bee Journal*. More broadly, adapting beekeeping and broader livestock management practices with microalgae feeds could contribute to achieving objectives outlined in the United Nations sustainable development goals related to food security, sustainable water management, reversal of land degradation, and halting biodiversity loss. The long-term aim of this research is to characterize and develop microalgae as a sustainable feed source for honey bees that can be augmented via biotechnology to improve bee nutrition and health.

Bee genomics reveals a genetic basis of colony defensive behavior. Breeding using genomic tools has not yet been adopted by the honey bee industry. In part, this is because some of the traits of highest interest for bee breeding are regulated by many genes, which makes it a challenge to characterize them. In addition, honey bees live as a colony, and many relevant honey bee traits are measurable only at the group level. Colony defensive behavior is an ideal example in which many of these complications are evident. This trait is of particular interest to stakeholders because having bee colonies that are overly defensive is undesirable from both management and public health perspectives. By investigating the genomic structure of this clearly identifiable behavioral trait and using a novel population of gentle Africanized honey bees local to Puerto Rico, ARS researchers at Baton Rouge, LA, were able to identify a particular region in the genome that contributes to reduced colony defensive behavior. These findings provide a roadmap for the analysis of complex bee traits.

Supplemental pollen feeding does not reduce varroa mite populations or virus levels in honey bee colonies. Varroa mites are the major cause of colony losses worldwide because they parasitize honey bee larvae and adults and transmit viruses. Beekeepers need management practices to reduce the impact of the mite, which migrates among colonies on foragers, and is difficult to control. Feeding pollen to bees can stimulate immunity, so ARS researchers in Tucson, AZ, tested for differences in mite population growth and virus levels in colonies with and without supplemental pollen feeding. Mite populations and levels of deformed wing virus rose throughout the season, were similar between fed and unfed colonies, and were correlated with the rate of mite migration into hives. Beekeepers can, however, still obtain some benefits from pollen feeding because it has been shown to stimulate colony growth and improve colony survival.

Climate change and bark beetle outbreaks affect alpine bee communities. Bees in alpine environments face many challenges, including harsh weather and finding floral hosts. Climate change can disrupt plant-pollinator systems through a temporal mismatch, if bees and flowering plants differ in their phenological responses to warming temperatures. While the cues that trigger flowering are well understood, little is known about what determines bee phenology. A 9-year study in the Colorado Rocky Mountains by ARS scientist in Logan, UT, found that bee emergence was sensitive to snowmelt timing, but that bee phenology was less sensitive than flower phenology to climatic variation, potentially reducing the synchrony of flowers and pollinators. However, large-scale outbreaks of bark beetles result in more dead trees but also greater diversity and number of flowers in the open canopy, which resulted in greater alpine bee diversity and numbers, suggesting that outbreaks may aid in conservation of pollinators in forests.

Access to U.S. Conservation Reserve Program (CRP) lands greatly improves honey bee colony health. The honey bee nutritional landscape is critical to the sustainability of commercial beekeeping and modern agriculture, but such landscapes are diminishing rapidly. ARS researchers in Tucson, AZ, exposed colonies to either USDA CRP lands or intensively cultivated landscapes and found that colony survival and future pollination potential were significantly improved by habitat conservation efforts. Colonies exposed to CRP landscapes showed markedly improved size, performance, and function. Mirroring these increases, functions that increase disease resistance were significantly greater in colonies exposed to CRP landscapes compared with those that were exposed to intensive agriculture. The study validates the overwhelming utility of U.S. conservation lands in pollinator health.

Blue orchard bees added to honey bees as cherry and pear pollinators increases fruit set, but not yield. Adding blue orchard bees (BOBs, *Osmia lignaria*) to Washington orchards already stocked with honey bees resulted in higher fruit set just after bloom had ended. ARS scientists in Logan, UT, found that cherry fruit set averaged 71 percent with BOBs and honey bees present, and 51 percent when only honey bees were present. Likewise, for pears, fruit set with

BOBs and honey bees averaged 31 percent and with only honey bees it was 24 percent. However, after fruit drop later in the summer and at final harvest, the gains in added fruit set did not result in higher overall yields. To optimize fruit yield, it will be necessary to continue to enhance management strategies for both the bees and the orchard crops.

Virulent strain of deformed wing virus (DWV) found in U.S. bees. DWV is the most widespread viral pathogen in honey bee colonies. In association with the parasitic varroa mite, it is one of the leading causes of honey bee colony losses. ARS scientists in Beltsville, MD, provided the first evidence of the presence of a virulent strain of DWV in a U.S. bee population and demonstrated that DWV types in U.S. bee populations are genetically distinct. This work highlights the complexity of DWV infection in honey bees and, in turn, can inform the design and development of therapeutic strategies for honey bee diseases. Progress will now be facilitated by the laboratory's development of a reporter gene, a green fluorescent protein that reports the presence of the virus.

New guides for detecting invasive bees. Detecting exotic bees at ports of entry is challenging, with an estimated 20,000 species of bees in the world. The second edition of the "Exotic Bee ID" guide was released in March 2020 by ARS systematists in Logan, UT, which significantly expanded the ability of inspectors and researchers to identify exotic species. The guide also includes nonnative bee species in the family Megachilidae (leaf-cutter bees) that have become established in the United States and already present threats to bee pollination in agricultural and natural ecosystems. This illustrated, interactive, web-based guide to the bee genera of Megachilidae will allow APHIS inspectors to identify bee genera and determine whether they are exotic or native. The guide will also be of use to pollination researchers, land managers, and interested naturalists in identifying native bees. Similarly, the researchers were able to use genomic data to differentiate 29 species of *Osmia* (mason bees), showing the power of new genomics efforts in systematics.

Detection of amitraz resistance and reduced miticide efficacy against parasitic mites. Beekeepers use many types of miticides, including amitraz, to control destructive varroa mites, the top killer of honey bees. ARS researchers in Baton Rouge, LA, evaluated mite resistance to amitraz in commercial beekeeping operations using two different methods, including one that can be easily conducted by beekeepers in the field. Significant amitraz resistance was detected only in two commercial beekeeping operations, so amitraz resistance appears to be rare. There was significant agreement with both tests, showing that monitoring for resistance could be implemented in a normal varroa mite monitoring program. It appears that amitraz use alone cannot account for the build-up of amitraz resistance in varroa, so more data on differences in operational use need to be collected. This research aims to establish a varroa resistance monitoring program over the entire country in order to detect and mitigate miticide resistance in varroa before it becomes widespread.

Honey bee social hygiene is enhanced by a propolis envelope. A propolis envelope is a layer of plant resin that bees apply throughout the hive. Honey bee colony losses by bacterial pathogens are often treated with antibiotics, but the overuse and misuse of antibiotics has spurred the development of alternative treatments. Scientists in Tucson, AZ, hypothesized that the antimicrobial activity of an experimentally applied propolis envelope would influence bacterial diversity and abundance in the colony. The experimental propolis envelope resulted in hives having fewer pathogenic and opportunistic microbes and thus better social hygiene, and the envelope also resulted in proliferation of putatively beneficial microbes on the honey bee mouthparts. This technology can be applied by commercial beekeepers to reduce the need to use antibiotics on honey bee hives.

Prospective diet additives rescue effects of pollen restriction. Microbial metabolites produced by gut bacteria are strongly influenced by diet and considered important drivers of bee health. Popular commercial diets used to supplement honey bees during forage dearth were not designed with microbiome health in mind. To evaluate the effects of fermentative metabolites on host endocrine function, ARS researchers in Tucson, AZ, fed pollen-restricted bees organic acid sodium salts (acetate, lactate, butyrate, formate, and succinate). Organic acid feeding rescued some effects of pollen restriction from situations in which the bees did not have enough pollen, thereby altering gene expression implicated in energy metabolism and feeding behaviors. These findings provide new insights into the diet-microbiota-host axis in honey bees and may inform future efforts to improve bee health through diet-based microbiota manipulations.

Cold storage of alfalfa leafcutting bees can reduce pollinator quality. Cold storage is used to manage bees such as the alfalfa leafcutting bee, which is used to pollinate some crops. Scientists in Fargo, ND, exposed developing bees to either a fluctuating thermal regime (FTR) or constant temperature during storage. Upon emergence, bees exposed to constant temperature storage were more likely to exhibit defects such as deformed wings, and even those without deformities were less likely to nest than their FTR counterparts, indicating additional damage as well. Surprisingly, the offspring of FTR-treated bees were more likely to enter the overwintering state of diapause than their untreated counterparts. This may be of critical importance to pollination service managers because the presence of non-diapausing bees is a key contributor to the transmission of diseases such as chalkbrood.

Forage quality found to be more important to honey bee colonies than pesticide exposure in agricultural areas. Exposure of bee colonies to pesticides is a major concern to commercial beekeepers. However, it is difficult for commercial operations to carry out precision monitoring of bee colony behavior and growth, and analysis of pesticide residue. ARS researchers in Tucson, AZ, monitored colony strength and thermoregulation as well as pesticide residues in 60 bee colonies, and found that although colonies in agricultural areas tend to have a higher diversity and concentration of pesticide residues, those hives were as healthy or healthier than hives in areas with little or no commercial agriculture. This information helps beekeepers put the roles of different bee stressors in perspective.

A simplified technique for storage of honey bee sperm germplasm. The current technique of honey bee sperm storage—cryopreservation—entails the use of potentially harmful chemicals and possible pathogen carriers that could reduce the quality of the sperm and the inseminated queen. Additionally, the technique requires specialized equipment, which limits the use of the technique by nonscientists. To solve these issues, ARS researchers in Fargo, ND, and Baton Rouge, LA, developed a better technique that uses a sugar-based antifreeze and a manual freezing technique to preserve sperm in liquid nitrogen to create a glass-like vitrified state. After storage, the sperm exhibited viability and mobility similar to those of untreated controls. This is the first report of bee semen vitrification, which will serve as the basis for a greatly simplified preservation protocol for the end user.

Suspected extinct Mojave poppy bee, a pollinator of bear poppies, found to be alive. The Mojave poppy bee (*Perdita meconis*) was first described in 1993 after being found pollinating the rare dwarf bear poppy (*Arctomecon humilis*) in Utah and later in 1995 in Nevada on another rare poppy, *A. californica*. Research indicated that this was a specialist bee for pollination of these rare plants. Since 1995, populations of Mojave poppy bees appear to have experienced severe declines in Utah. Surveys for this bee on dwarf bear poppy in Utah in 2012, 2016, and 2017 yielded no Mojave poppy bees. This lack of detection has resulted in the conclusion that the species had become locally extinct in Utah. Surveys in 2020 at multiple sites in Nevada led by ARS scientists in Logan, UT, documented the presence of the Mojave poppy bee on multiple populations of *A. californica*, suggesting that this specialist bee is still providing pollination services essential for survival of these endemic plants in Nevada.

Complete genome of an orchard crops pollinator. The blue orchard bee (BOB), *Osmia lignaria*, is a more efficient pollinator of orchard crops than the honey bee. But unique, regionally adapted biotypes of the BOB are facing possible extinction due to interbreeding with other biotypes used by commercial suppliers for pollination services. The loss of these regionally adapted biotypes will have a long-term negative impact on tree fruit production in the Pacific Northwest. To address this problem, ARS researchers in Fargo, ND, have completed a highly refined complete genome of the BOB. ARS researchers in Logan, UT, are currently using this new genome to determine the geographic distribution of BOB biotypes. These activities will significantly contribute to the conservation of this commercially important pollinator.

Rearing queen bees in the laboratory. In a bee colony, worker bees can feed a larva a custom diet and cause the larva to develop either into a worker or a queen. If researchers were able to determine the differences in the worker or the queen diet, they could rear the queen bees in the laboratory and create a complete honey bee colony. ARS researchers in Fargo, ND, collaborating with scientists at North Dakota State University, demonstrated that it is the quantity, not the quality of the diet that is important in this differentiation process. Larvae that were fed less of the diet became worker bees, and those that were fed more of the same diet became queens. This insight opens new avenues of research into queen health and the development of new techniques in queen rearing.

Development of a gene silencing strategy for controlling honey bee chalkbrood disease. Chalkbrood disease is caused by a fungal pathogen that kills larval bees. RNA interference (RNAi) is a natural mechanism to silence gene expression and is used by many different organisms to defend against pathogenic infections. ARS scientists in Beltsville, MD, demonstrated that decreasing the expression of a gene that is specific for the causative agent of chalkbrood disease using RNAi-based strategies could reduce germination rates of this fungal pathogen. This study demonstrates that RNAi technology holds much promise as a therapeutic strategy for treating this honey bee disease.